CONTROLLER DESIGN FOR PERFORMANCE ENHANCEMENT OF MICROGRID

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to

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by

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ABSTRACT

Renewable energy strategy is getting more intrigue because of extending demand and danger zero carbon impressions. The increasing demand of renewable energy tends to generate a output power that is having quality in terms of the grid integration. The rise in energy demand along with the environmental concerns in fossil fuel resources has necessitated the incorporation of renewable energy techniques to the mainstream of electrical energy sector. Integration of flexible and non-dispatch able renewable energy production will influence the operation and future expansion of prevailing power systems. This research work focuses on various methods and technologies used to investigate new concerns dynamic stability of power system and control performance of the power system with regards to expanded micro grid penetration.

The expanded penetration of microgrid can influence the system stability to the power system because there is dissimilarity in dynamic characteristics of the microgrid and the conventional generators. Because of the variations in performance responses between Micro grid and regular generators, including Renewable Energy Sources-based Microgrid into the electrical system may have an influence on stability analysis. The reduction in switching frequency induced by these energy processors electronic interconnected electricity producing sources has a detrimental impact on the system's structural analysis, potentially leading to stability issues. Power infusion from Renewable Energy Sources-based microgrid, on the other hand, increases damping efficiency, reducing transmission line congestion and power shortage. In this work a model based on extreme learning machine (ELM) for short-time wind power prediction is to be constructed. Then, Artificial neural networks (ANN) will be used to optimize the type, bias, input weight and regularization coefficient of the activation function for extreme learning machine, thus the prediction model for wind power based on ANN-ELM will be obtained. Outcome of research work shall lead to high stability and short transient of Renewable energy system.

Keywords: Renewable Energy Sources (RES), Microgrid (MG), proportional–integral–derivative controller (PID Controller), wind energy conversion system (WECS).

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1. INTRODUCTION

Energy resources Conservation, sustainable development and protection of environment are the three of the major challenges at present that the world faces. One important concern is to make certain the requirement of energy for people does not cause rapid reduction of the natural energy resources and indignity of the environment. Renewable energy resources are the real alternatives to the conventional forms of energy and play an important role in reducing energy-related emissions. Renewable energy is clean and contaminates and does not produce any greenhouse gases or any wastes in the task of production of electricity. It is a feasible source that is depended on for long time duration. Renewable energy is efficient and cost effective. Solar energy, biomass, Wind, geothermal, and hydro energy are in the forefront among the various sustainable energy forms, all of which are abundantly available on our planet for most of which the fundamental resource is the sun. Among these, wind energy is the most promising and famous efficient power vitality source all over the world. Despite the fact that the possibility of mechanical power from wind energy is hundreds of years old, wind energy of commercial-scale has been generated most effective for the last 2 to 3 decades and has become economically possible just over the most recent couple of years (Rahman, 2003). Electricity generation from wind makes economic in addition to environmental experience. Wind is free and it is a clean energy resource; it will never run out. A wind turbine creates reliable, cost-effective, pollution free energy in mechanical form that can be converted into electricity with ease.

The industry of wind energy making and designing wind turbines, raising and running them is developing quick and is set to grow as the world searches for cleaner and sustainable ways to produce power. Wind Turbines are turning out to be less expensive and powerful, with bigger sharp edge lengths which can use more wind and in this manner produce greater power, cutting down the cost of generation of renewable (Tiwari and Babu, 2016).

Although wind energy is considered to be a promising resource by most of the power and energy engineers, it is generally acknowledged that its variable nature prohibits it from being used as the single major energy resource in any system.

1.1 RES AND ASSOCIATED CONTROL ASPECTS

There is an entire wide range of distinct design philosophies for rectifiers, frequency converters and inverters for the variable speed wind energy conversion system. During ongoing years diverse converter topologies have been explored for their applicability in wind energy conversion system. They are mainly multi-level converters, back-to-back, matrix,

resonant and tandem converters. The back-to-back converter is profoundly applicable to Wind turbines today and they may be utilized for benchmarking the other topologies of converter. Matrix converter and multi-level converters are almost genuine contenders to the back-to-back converter. Typical self-commutated converters are dominating the market as they consist large switching frequencies and harmonics can be separated out without any problem. By utilizing the pulse width modulation method, lower frequency harmonics can be removed; the frequencies of the 1st higher order harmonic exist at around the switching frequency of the rectifier or inverter (Müller, Deicke and De Doncker, 2002).

A configuration of diode rectifier – chopper – inverter is selected for smaller systems, as this is simple and cost-effective. For high power wind energy conversion system using permanent magnetic synchronous generator, completely controlled pair of rectifier – inverter is typically utilized, along with control of a vector torque design for changing operation of speed (Han, Zhang, Yin and Wang, 2008). The power factor regulation of the wind generator is achieved through vector control of grid side converter. A pulse width modulation current source converter for grid side converter is also an option for permanent magnetic synchronous generator based WECS.

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1.2 RES AND POWER SYSTEM INTERACTION

The impact of a projected total wind penetration of 3000MW in the Greek power system is investigated. System is modeled to compare low voltage ride through capabilities of a constant and varying speed wind energy conversion system and it is realized that varying speed WECS have a better low voltage ride through capability which reduces generation losses and limits outages. A case study for transient stability of wind turbine and the impacts of a three short circuit fault on the power grid is presented (Voumvoulakis, Markou and Hatziargyriou, 2008). It is observed (Yang *et al.*, 2009) that voltage stability isn't just correlated to the qualities of wind turbine yet in addition has cozy relationship with the power grid.

Estanqueiro highlighted the current technical obstructions that forestall accomplishing a excessive wind penetration in a power system.

The problems related to limited transmission capacity, supply security, power unit scheduling, variability of wind, reliability and operational energy congestion are reported. Technical solutions for wind power control, low voltage ride through and curtailment, remote control of reactive power are also discussed. Muljadi (Tapia *et al.*, 2003) endeavors to examine the impact of wind power penetration on transient stability of grid and the results are

proposed as basic critical clearing time. Rodriguez (Higuchi, Yamamura, Ishida and Hori, 2000) presented the fundamental examination of the impact of penetration of high wind power. Tripping of wind generators due to short circuit fault is reduced in case of doubly-fed induction generator and also voltage recovery is very fast whereas squirrel cage induction generators is sluggish. For the same fault, voltage in doubly-fed induction generator recovers in 0.4 sec whereas in fixed speed squirrel cage induction generator it occurs 0.5 sec. It is concluded that a huge amount of uncontrolled wind production connected in little territories could have negative effect on system dynamics; so a variable speed system or carefully designed dynamic voltage support system is recommended.

1.3 IMPACT OF RES BASED MICROGRID PENETRATION ON POWER SYSTEM PERFORMANCE

Power System integrated with renewable energy resources are becoming very popular and penetration level of Renewable energy sources is increasing because of decrease in reserves and increase in price of fossil fuels. Intrinsic nature and variable generation from Renewable energy sources poses challenges to integrate them with the power system and maintain stable electrical power system.

An important issue when integrating Renewable energy sources to power system is the effect on the transient behavior and the system stability. System stability is to a great extent connected with power system faults in a system for example, loss of generation capacity (failure of generator unit), short circuits and tripping of transmission lines. Huge voltage drops suddenly may occur, despite the fact that the capacity of the working generators might be satisfactory.

2. LITERATURE REVIEW

Renewable energy method is acquiring more interest because of increasing demand. The growing demand of Renewable energy tends to deliver output power of quality in terms of grid integration. So efficient controller is needed to control the power produced by Renewable energy sources. Many research publications had reviewed the different control strategies. Thus, Literature presents a complete review of numerous control techniques for Renewable energy sources.

i. To improve pitch control of a wind turbine

There is a Proportional Integral Derivative controller (PID) that is the mostly utilized for controlling the pitch of wind turbines. Yet, because of unpredictability in wind speed profiles and wind turbine modeling, there is requirement of increasingly successful controller. An advanced controller called fractional-order fuzzy Proportional integral derivative controller has been presented in the literature Asgharnia, Shahnazi and Jamali (2018) to enhance the performance of pitch controlling of a wind turbine that is of 5-MW. The chaotic evolutionary optimization techniques are utilized, for determining the controller parameters, in the meantime. Different wind speed profiles and divergence has been applied to ideal controllers and their responses have been contrasted with 4 appropriate measure. The outcomes of simulations exhibit that the presented controller has greater fitness and outcome in reducing the integral absolute power error, integral absolute error, integral absolute low-speed shaft torque error furthermore, then again, in limiting the fatigue damages over Fuzzy proportional–integral–derivative, Gain-scheduling PID and Fractional-order PID controllers. Meaning of Less integral absolute error is less generator speed error. Meaning of Less integral absolute power error is better regulation and power quality.

ii. To reduce chattering phenomenon

A control strategy Super-Twisting sliding mode control for wind energy conversion system having Doubly fed Induction generator has been presented in the literature Boubzizi, Abid, hajjaji and Chaabane (2018). The Super-Twisting methodology is more influential in the matter of energy extraction augmentation, power quality, chattering minimization, higher perfection and stoutness to system disturbances and parameters changes as compared to Proportional-Integral and conventional Sliding Mode controllers. To minimize chattering process in active power and reactive power and distortion of rotor-side converter, current in a wind turbine which is Doubly fed Induction generator based, Benamor, Benchouia, Srairi and Benbouzid (2019) a control methodology has been proposed. Root tree optimization is utilized to modify the parameters (Kp, Ki) of PI controller. The simulations outcomes manifest that the presented controller adequately boosts the control performances of turbine which is Doubly fed Induction generator based in terms of steady-state performances, greater dynamics and chattering phenomena limiting, switching frequency decrease.

iii. To damp the oscillations

Raya, Paitala, Mohantyb and Panigrahia (2017) proposed the study of grid dynamic stability connected power system which is solar energy based under different operating scenarios. When the machine is exposed to minor disturbances, dynamic stability issues happen in the rotor and that turns into a difficult job because of high penetration of solar photovoltaic. The work presents a composite optimization technique which is dependent on Particle Swarm Optimization technique and Gravitational Search technique to tune proportional integral derivative controller. The comparison of simulated responses of Particle Swarm Optimization-Gravitational Search optimized PID, conventional proportional integral derivative controller and Particle Swarm Optimization dependent proportional integral derivative controller was obtained. So this was concluded that the presented strategy Particle Swarm Optimization-Gravitational Search based PID is diminishing the oscillations very effectively in comparison to the different controllers which proves the system stability.

The Static Var Compensator incorporated with Proportional Integral Derivative controller is integrated with the photovoltaic based power system in single machine infinite bus for reducing low frequency oscillations created because of disturbances in the system for improvement of transient stability Paitala, Raya, Mohantyb and Das, (2018). To differential search algorithm, quasi oppositional learning was integrated for determining the optimized of Static Var Compensator-PID controller parameters. The presented strategy quasi differential search algorithm dependent PID is reducing the oscillations most effectively in comparison to conventional PID, Particle Swarm Optimization optimized PID, differential search algorithm optimized PID which demonstrates its ability in improving the stability of the system very efficiently.

Corradini, Ippoliti and Orlando (2017) fascinated on varying-rotor-speed and wind turbines that is dependent on changeable-blade-pitch which operate in the high wind speed zone, where torque of generator and pitch of blade controllers are used to control the capturing energy of turbine to the rated power value. In the literature Ebrahim, Becherif and Abdelaziz (2018) the blade pitch controller incorporated with Proportional-Integral-Differential for the wind energy conversion system to upgrade the oscillations damping in the voltage and output energy has been investigated. The turbine system which is single wind is connected with blade pitch controller-PID. Moth flame optimization is used to search for optimized parameters of the controller. So, the presented design can ensure the system stability. Responses of simulation accentuation on the finer execution of the presented Moth flame optimization based blade pitch controller-PID in comparison to the traditional blade pitch

controller-PID dependent on Zeigler Nichols, blade pitch controller-PID based on simplex algorithm, and genetic algorithms-based Proportional-Integral-Differential controllers in capturing system nonlinearities above an extensive span of working conditions and vulnerabilities of control system parameters. To achieve a constant regulated output voltage in wind energy conversion system Robust control technique is required. So a Fractional order Proportional Integral controller is designed that uses Genetic algorithm for tuning and implementation using MATLAB/ SIMULINK. The robustness characteristic of fractional order proportional integral controller is that the proposed controller is less Oscillation and regulated output voltage, overshoot problem is not there. A control strategy which is dependent on Type 2 Fuzzy Logic Controller to control the active power and reactive power of the doubly-fed induction generator of wind energy conversion systems was implemented as well as examined using MATLAB/Simulink. The outcomes manifest that the proposed controller is having good performance, very good convergence, does not consist any oscillation or overshoot and it is fast as compared to the Type 1 Fuzzy Logic Controller method Belabbas, Allaoui, Tadjine, Denaï (2018).

The effect of micro grid penetration which is based on renewable energy sources on the control and stability of a Two-area four generators system having renewable energy sources based micro grid under differing working conditions is investigated. Power system stabilizer which is based on a type-2 fuzzy fractional order Proportional Integral Derivative is designed to improve the oscillation damping execution for the power system for upgrading the stability. Optimized Parameters for type-2 fuzzy Fractional order Proportional Integral Derivative controller are determined by an effective hybrid algorithm in which dynamic genetic algorithm is integrated to bac-teria foraging algorithm. The hybrid control technique provides the benefit of lustiness against all vulnerabilities that are available in the system. The complete analysis manifests that, when tuning of a fractional order PID based Power system stabilizer is done for the ostensible system and executed, it does not need the tuning again in the dynamic power system for any annoyed conditions and in this manner guarantees the system authenticity. The results of nonlinear simulation exhibit the effect of the parameter impact on the finest effective response of the system with different micro grid penetration ratios under various operating disturbance vulnerabilities and conditions. Kuttomparambil Abdulkhader, Jacob and Mathew (2019) introduced that to represent the predominance for a fractional order PID based Power system stabilizer, its performance is compared to the another kinds of Proportional Integral Derivative based Power System Stabilizers.

A framework has been projected in the literature Jabr, Lu, and Kar (2011) to control for wind driven Double fed Induction Generator based on neuro fuzzy vector method. But use of Double fed Induction, a more practical alternative over the absolute life pattern of the turbine and neuro fuzzy controller quite complex because the error value of generator speed is a input of each neuro fuzzy system and multi hidden layer processing.

For varying pitch wind energy conversion system a neural network controller has been proposed in the literature Ren, Zhang, Tian and Hou (2014). using generalized reduced entropy. In this work neuro-fuzzy controller has been used. This technique contrasts from past outcomes in reduced entropy control: this strategy dodges the development of model of a system. In this approach the nodes are fixed due to which number of inputs and their parameters are also fixed. Damiano, Scano, and Varone (2020) introduced a method to design a microgrid which is supplied by renewable energy sources for the attainment of an energy community. Emara et al. (2021) presented the improved operation and control of DC microgrid systems, that are based totally on battery storage systems, photovoltaic modules and DC load. To acquire such an bold target, the system is broadly operated in two different modes that are: grid-connected and stand-alone modes.

3. GAPS IN RESEARCH STUDY

- The controller parameters influence the performance of a WECS to a great extent. So as to guarantee the satisfactory working of controllers the parameters ought to be determined in coordination with each other. Computational burden that arises while tuning the controller parameters for a large wind farm is an issue of concern.
- Use of traditional hybrid algorithm results in complex and costly outcomes.
- No backup (storage) for microgrid in case of fault occurrence.
- In the phase of development of variable speed WECS, use of doubly-fed induction generator increases processing cost.

4. OBJECTIVES OF THE STUDY

4.1 Problem Statement Formulation:

Literature review reveals that, in a power system, to reduce the double frequency oscillations that arise because of unsymmetrical disturbances, a damping controller is developed. The impacts of such type of oscillations are reflected in the active power that penetrates in to the grid. The control structure of the wind energy systems can be optimized to limit such type of oscillations.

The problem of proposed research is to ultimately improve the double frequency oscillation of wind based system by designing an effective controller.

4.2 Objectives of the research:

- To explore different Microgrid stability related issues and types of wind driven generators for better performance of the Renewable energy systems.
- To design a Controller to improve the performance of Microgrid.
- To optimize the controller parameters by using an artificial intelligence technique.
- To enhance the dynamic stability of power system having Renewable Energy Sources based microgrid penetration

5. METHODOLOGY TO BE ADOPTED

Methodology for the proposed research work is represented by the block diagram shown in the following figure 1.

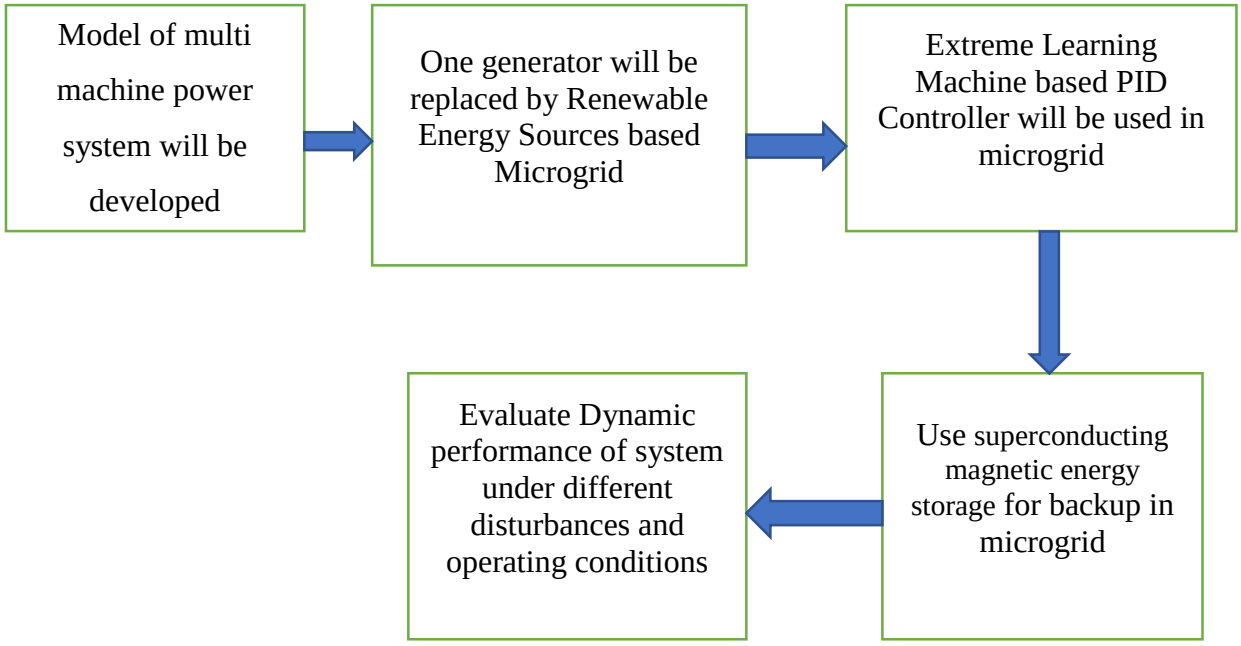
Model of multi machine power system will be developed
One generator will be replaced by Renewable Energy Sources based Microgrid
Extreme Learning Machine based PID Controller will be used in microgrid
Use superconducting magnetic energy storage for backup in microgrid
Evaluate Dynamic performance of system under different disturbances and operating conditions

Figure 1. Methodology of the proposed work

6. EXPECTED OUTCOME OF THE RESEARCH

- Better dynamic response, better control of power of renewable energy based systems.
- A controller design would be developed for better control of power and better dynamic response of renewable energy based systems.
- Higher degree of robustness of proposed plan against system parameters vulnerabilities.
- It is expected to publish 04 research papers through this thesis.

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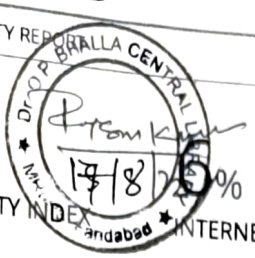

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